AMENDMENTS TO THE SPECIFICATION

Under "STATEMENT OF GOVERNMENT INTEREST"

~~The invention described herein may be manufactured and used by or for the Government of the United States of America for governmental purposes without the payment of any royalties thereon or therefor.~~ Under paragraph 1(a) of Executive Order 10096, the conditions under which this invention was made entitle the Government of the United States, as represented by the Secretary of the Army, to the entire right, title and interest in any patent granted thereon by the United States. This and related patents are available for licensing. Please contact Bea Shahin at 217 373-7234 or Phillip Stewart at 601 634-4113.

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Under "BRIEF DESCRIPTION OF DRAWINGS"

Figure 1 shows ~~how water currents are~~ a horizontal eddy generated by the action of an intake in a dam, as a side view ~~taken~~ ~~through a cross-section~~ of a body of water cut vertically along the direction of flow of a body of water backed up by the dam without a preferred embodiment of the present invention installed.

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Figure 2 is a perspective illustration of a body of water depicted as a stream, showing stream edges and elevation cross-sections at different parts of the stream for purposes of illustrating coordinates used in explaining the invention.

Figure 3A depicts velocity gradients in a direction parallel to the *x*-axis (the length) of the stream of Fig. 2 ~~and through a slice of an elevation cross-section taken~~ and in a single horizontall~~y~~ plane along the *y*-axis ~~for~~ (the width) of ~~a~~ the stream at one location along the *x*-axis.

Figure 3B depicts velocity gradients in a direction parallel to the *x*-axis (the length) of the stream of Fig. 2 ~~and through a slice of an elevation cross-section taken~~ and in a single vertical~~ly~~ plane through ~~the elevation at~~ one point ~~across~~ along the y-axis (the width) of ~~a~~ the stream.

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Figure 4 illustrates the dam and body of water depicted in Fig. 1 with ~~a vertical cross-section of a dam incorporating, and illustrating the practice of, the natural cue surface bypass as~~ a preferred embodiment of the present invention installed, showing the change in the horizontal eddy induced thereby.

Figure 5 ~~is a perspective view of a~~ shows salient features of a preferred embodiment of the collector of the present invention to include the direction fish enter.

Figure 6 ~~is a perspective view of~~ shows the collector of Fig. 5 with ~~illustrations showing preferred~~ two alternate means to transition, size and locate water and fish handling systems ~~of a preferred embodiment of the collector gallery of the present invention~~ using either a common collector galleries or separate collector galleries for each installed unit of the invention.

Figure 7 depicts the body of water and dam of Fig. 1, for illustration purposes only omitting the invention as shown in Fig. 4, to illustrate the change from the vertical eddy of Fig. 1 without the present invention to a horizontal eddy or "roller" ~~in a view of a vertical cross-section of a dam~~ when incorporating a preferred embodiment of the present invention. ~~The invention is not shown in this figure, just the result of its use.~~

Replace the paragraph beginning at page 8, line 25 with:

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Refer to Fig. 1. Shown is a ~~vertical~~ horizontal eddy 101 formed by the action of water streaming through an intake 403 of a dam 402 and located beneath the water surface 404 and above the turbine intake 403. Streamlines 405 depict the paths individual particles would take in the flow field as they either enter into the intake 403 or circulate in the eddy 101. Downstream water velocities increase substantially at the top and bottom of the intake 403 producing zones of

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high strain 102. Fish are known to avoid zones of high strain 102 indicated by changes in the direction or spacing of the stream lines. This configuration, if uncorrected, assures that some fish, in particular juvenile fish migrating downstream, as explained later, will be lost in seeking out a way around the dam 402 ~~the hydraulic cue of the eddy 101~~ and thus be delayed or prevented from their downstream movement or enter the unforgiving intake 403 or be tossed against the trash rack 406. A preferred embodiment of the present invention insures that this can not happen.

Replace the paragraph beginning at page 9, line 12 with:

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Refer to Figs. 2, 3A and 3B. A cross-section 10 with water surface elevation ~~11~~ 20 ~~from Fig. 2~~ shows multiple velocity vectors, u 1~~2~~1, in the x-y plane 14 at a constant z and multiple velocity vectors, u 1~~2~~1 in the x-z plane 1~~3~~8 at a constant y. In simple, straight natural channels 8, water velocities at physical boundaries 16 (e.g., where the water comes in contact with the stream bottom, boulders (not shown separately), or stream edges 9) are zero and increase away from the boundaries 16 to a maximum value 17 equidistant from the friction effects of the opposing boundaries 16 (after the effect of the boundary 16 has been corrected for differential roughness). The *rate of change* in velocity of "downstream" flow over distance, i.e., the strain rate, mathematically defined as the derivative of the u 11 vector, laterally ($\frac{\partial u}{\partial y}$) or with depth ($\frac{\partial u}{\partial z}$) has its greatest absolute values near the boundaries 16 and its smallest values at the "belly" 17 of the velocity profiles 19A, 19B shown by the curved dashed lines. In addition to the belly 17 being the zone of maximum mean water velocity, theoretically it is also the zone where the *rate of change* in down stream velocity with respect to either the z or y direction is zero. Mathematically this is expressed as:

$$\frac{\partial u}{\partial y} = \frac{\partial u}{\partial z} = 0 \qquad (1)$$

Replace the paragraph beginning at page 9, line 27 with:

Equation 1 embodies the mathematical description of the downstream migratory behavior of juvenile fish in simple, straight natural channels. That is, juvenile fish select swim paths that minimize the strain rates ($\frac{\partial u}{\partial y}$) and ($\frac{\partial u}{\partial z}$), once a certain strain value or threshold is met, by swimming in the direction of maximum velocity magnitude. ~~and are thereby able to~~ This behavioral rule allows outmigrating fish to consistently locate themselves in the portion of the river having the highest average downstream water velocity. In this way, fish can minimize the time of their journey and minimize their expenditure of energy during their migration to the ocean. This zone is where fish concentrate so any artificial device would be optimized by location there or at an artificial device that creates a hydraulic environment that similarly minimizes the absolute value of the strain rates, ($\frac{\partial u}{\partial y}$) and ($\frac{\partial u}{\partial z}$) and provides a small velocity signature. This will attract fish because approaching fish would interpret the artificial environment as being their optimum pathway to the ocean.

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Replace the paragraph beginning at page 10, line 9 with:

Refer to Fig. 4. Shown is a profile of a preferred embodiment of the present invention. i.e., a natural cue surface bypass collector (NC-SBC) 400, consisting of an "oven hood" surface bypass collector (OH-SBC) 401, attached to a dam 402 just above the turbine intake 403 with reference water surface 404. The shape of the OH-SBC 401 gives it its name; since when viewed from the front it closely resembles the oven hood used to exhaust cooking smells and smoke from a stove top. Streamlines 405 depict the paths individual particles would take in the flow field as they approach and enter the trash rack 406. The OH-SBC 401 has the following unique design features:

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an extension 407 projects upstream of the dam 402 to eliminate the ~~vertical~~ horizontal eddy 101 commonly encountered above intakes;

an internal space 408 defined by the outer extension 407, where the internal space may be an isolated chamber or part of a sluiceway;

a collector gallery 409 that parallels the internal space 408 (as each space may be envisioned running into and out of the paper in Fig. 4) and is separated from it by a solid wall 420 (or the solid wall could be replaced by a de-watering screen);

an articulating, adjustable extension 410 that partially controls the angle of attack of the water that flows under the collector gallery 409;

a hydrodynamic sensor 411 that monitors water velocity and other hydraulic conditions that can be used to remotely adjust the articulating extension 410; and

adjustable attachment points 412 at the face of the dam 402 that allow dam operators to raise or lower the OH-SBC 401 to optimize its efficiency as water levels fluctuate.

Replace the paragraph beginning at page 11, line 1 with:

Refer to Figs. 4 and 5. The OH-SBC 401 causes the gradient represented by the absolute value of $\frac{\partial u}{\partial z}$ 413 to decrease toward the slot opening 501 to the collector gallery 409. A fish's natural instinct will cause it to pursue this decrease in gradient and move towards the collector gallery 409 rather than to the turbine intake 403, particularly if a small attracting inflow is also provided at the slot opening 501.

Replace the paragraph beginning at page 11, line 5 with:

Refer to Fig. 5. Shown is a three-quarters perspective view of one module of the OH-SBC 401 showing the slot opening 501 into the collector gallery 409 and the following design features: side wall to the collector gallery ~~502~~420, extension 407 to the OH-SBC 401 and articulating extension 410. The OH-SBC 401 may be connected to an orifice in an ice and trash

sluice gate (not separately shown) or to other conventional means of conveying fish around a dam 402.

Replace the paragraph beginning at page 11, line 11 with:

Refer to Figs. 4 and 6. Shown are both a three-quarters and two bottom view perspectives of a three-module OH-SBC 401A, 401B, 401C. The two bottom view perspectives describe the two options available for conveying water among the three modules 401A, 401B, 401C. The upper bottom view perspective 610 describes a manifold system 601 that can be employed in which the water entering ~~from~~ each module 401A, 401B, 401C through the slot opening 501 is maintained in ~~respective~~ separate chambers ~~602~~ 409A, 409B, and 409C until discharged into ~~a~~ separate bypass channels 603A, 603B, and 603C, respectively. The separate bypass channels 603A, 603B, 603C eventually merge into a combined bypass channel 603. The method of operation is illustrated by the separate paths made by three individual fish along paths 602 moving through the manifold system 601. The internal space 408 in the extensions ~~408~~ 407 exist as separate chambers and do not connect with the gallery 409. The internal space 408 in the extensions ~~408~~ 407 may be filled with floatation to accept some of the weight load of the OH-SBC 401 from the dam 402. Standard engineering practice can be used to transition, size and locate the connections of the manifold 601 to its exit to the bypass channel 603, with the requirement that all structural elements and design features must either minimize or hold constant the absolute value of the strain rate variables in the *x* (downstream) direction, and provide a small net flow towards the bypass channel 603. The net flow towards the bypass channel 603 attracts outmigrating fish thereby ~~This~~ preventsing them ~~fish~~ from reversing their path ~~through~~ and rejecting the OH-SBC 401. The manifold system 601 has the advantage that it is modular and can be relatively easily expanded since the de-watering system is separate for each module 401A, 401B, 401C. Alternatively, as shown in the bottom most figure 620, modules 401A, 401B, 401C can be connected so that they share a common collection gallery system ~~604~~ 605 and a common extension gallery system ~~605~~ 606 by removing the sidewalls ~~502~~420 between each module 401A, 401B, 401C. The wall 606 separating the collection gallery system 604 from the extension gallery system 605 can be replaced by a single set or multiple sets of de-watering

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screens 607. The de-watering screens 607 allow the controlled passage of water (illustrated by the three stream lines 608) into the collection gallery system ~~604~~ 605 from the dam forebay but prevent the entrance of fish into the extension gallery system 606. The water from the extension gallery system 606 can then be collected in a discharge pipe (not shown separately) and routed to a turbine (not shown separately) where it can be used to generate power or be passed around the dam 402. Fish concentrated in the collection gallery system ~~604~~ 605 can be routed through to a bypass channel 603 to be bypassed around the dam 402. The advantage of the continuous system is that less water needs to be handled by the bypass channel 603. Standard engineering practice can be used to size and locate the de-watering screens ~~603~~ 607 with design features that minimize or hold constant the absolute value of the strain rate variables in the *x* (downstream) direction.

Replace the paragraph beginning at page 12, line 11 with:

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Refer to Fig. 7. Shown is a profile of a dam 402 at the intake 403 of a hydropower turbine showing the presence of a ~~vertical~~ horizontal eddy, or roller ~~101~~701 immediately above the intake 403 and between the dam 402 and the point 702 where the stream lines are directed towards the intake 403. The minimum absolute value of $\frac{\partial u}{\partial z}$ 413 in the upper part of the hydropower intake plume represented by the stream lines 405 is least towards the center ~~413~~ of the eddy ~~101~~701 as indicated by the gradient $\frac{\partial u}{\partial z}$ 413. Therefore, juvenile fish in the zone of the stream lines 405 will be attracted into the area formerly occupied by the eddy ~~101~~701 (particularly if it is replaced by an attracting flow) where they will follow a path that is most like what occurs in a natural migration.

Replace the paragraph under "EXAMPLE" beginning at page 12, line 21 with:

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Outmigrating juvenile fish make use of hydraulic cues to navigate their way through the complex flow fields of natural streams and rivers, particularly in muddy water or at night when visual acuity is impaired. Refer to Fig. 2. The natural flow fields of simple (approximately u-

shaped in cross section), straight stream channels 8 are described mathematically as velocity vectors u 11 in the direction of stream flow in its channel 8 (x-direction) either across the stream from streamside 9 to streamside 9 (y-direction) or in the direction of the depth of the stream (z-direction). The most important direction for purposes of fish migration in simple channels 8 is the x direction, the velocity represented by the u vector 11. The acceleration terms, a_u, a_v and a_w, represented mathematically as the derivative of the velocity terms, provide the acceleration in the direction of the u 11, v 12 and w 13 velocity vectors, respectively, and may also play a role. In natural channels, u 11 at solid boundaries, such as the sides 9 and bottom of the channel 8, has a theoretical zero value because of friction and increases at a high *rate of change* away from the solid boundaries (i.e., where the water comes in contact with the stream sides 9 and stream bottom) to a maximum average water velocity approximately equidistant from the friction effects of the solid boundaries (after the effects of the various boundaries have been corrected for differential roughness). As the water velocity approaches maximum, the *rate of change* in velocity approaches zero. This zone of maximum average water velocity is important to migrating fish because it represents, on average, the greatest velocity in the cross section and the swim pathway to the ocean that requires the least expenditure of energy by actively migrating fish. In addition to minimizing resistance, this zone maximizes the size of the sensory envelope within which fish are able to detect and avoid predators, and maximizes their ability to detect and orient to hydraulic cues. Fish use this zone as the optimum pathway through complex river channels 8.

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Replace the paragraph beginning at page 13, line 16 with:

Refer to Figs. 3A and 3B. The *rate* of change in velocity vectors is embodied in the hydraulic strain rate or tensor variables, $\frac{\partial u}{\partial x}, \frac{\partial u}{\partial y}, \frac{\partial u}{\partial z}, \frac{\partial v}{\partial x}, \frac{\partial v}{\partial y}, \frac{\partial v}{\partial z}, \frac{\partial w}{\partial x}, \frac{\partial w}{\partial y}, and \frac{\partial w}{\partial z}$. For example, the *rate* components of u 11 with respect to the stream width (y-direction), $\frac{\partial u}{\partial y}$ or stream depth (z-direction), $\frac{\partial u}{\partial z}$, have the smallest absolute *rate of change* values near the belly 17 of the velocity

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profile 19A, 19B and their greatest absolute *rate of change* values at the boundaries 16 as shown in Figs. 3A and 3B, respectively. Fish have a sensory system and behavior that cues into this natural pattern to find the optimum pathway. That is, outmigrating fish select the swim path through the river that minimizes the absolute value of the tensor variables in the flow field. In particular, in simple, straight channels 8 they minimize the absolute value of the *rate of change* $\frac{\partial u}{\partial y}$ *and* $\frac{\partial u}{\partial z}$, and thereby locate themselves over the deepest part of the channel 8 about equidistant from both shores 9 as much as the sensitivity of their sensory system allows. In addition to being the zone of maximum mean downstream water velocity, this zone is also where the changes in either the v 12 or w 13 components of velocity are also zero, i.e., mathematically, $\frac{\partial v}{\partial y} = 0, \frac{\partial w}{\partial z} = 0$. Thus, the "side slip" from the v 12 component and the "up" or "down draft" from the z 13 component are minimized. Facilitating a fish swim path selection behavior that minimizes the absolute value of $\frac{\partial u}{\partial y}$ *and* $\frac{\partial u}{\partial z}$ allows fish to find and maintain position in this critical zone.

Replace the paragraph beginning at page 14, line 5 with:

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Refer to Figs. 4 and 5. The design for the natural cue surface bypass collector (NC-SBC) 400 departs from the usual design criteria of imposing an attracting intake plume on the overall hydraulic pattern in the forebay of the dam 402. Instead, the new design, by its shape and position, slightly modifies the existing flow field 405 at the dam 402 immediately above the intakes 403 to create a flow minimizing the absolute value of the natural hydraulic cues, e.g., $\frac{\partial u}{\partial y}$ *and* $\frac{\partial u}{\partial z}$, at the slot entrance 501 of the collector gallery 409. This design feature causes outmigrating fish to swim to the slot entrance 501 instinctively in the same way they find the optimal swim path zone in the channels 8 of natural rivers and streams. Once juvenile fish have been attracted into the collector gallery 409, they are conveyed around the dam 402. Standard engineering practice is employed in designing the necessary outlet flows for the NC-SBC 400,

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following design criteria of minimizing the absolute value of the strain rate variables in the direction the fish are to be conveyed around the dam 402.

Replace the paragraph beginning at page 14, line 18 with:

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The main body of the OH-SBC 401 defines a channel, i.e., the collector gallery 409, and is made of structural iron or other appropriate material. The inner side of the OH-SBC 401 is made to be as smooth as possible to minimize the creation of turbulence and is coated with a neutral color, such as battleship gray, to avoid the possibility of providing visual cues to the fish. The upstream edge 414 of the OH-SBC 401 is wedge shaped and designed to completely fill the space above and upstream of the hydropower turbine intakes 403 that usually contain either a hydraulic eddy 101 or a hydraulic dead zone (not shown separately).

Replace the paragraph beginning at page 14, line 25 with:

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Refer to Figs. 1, 5 and 7. The upstream pointing extension 407 redirects the flow field so that the ~~vertical~~ horizontal eddy 101 is completely enclosed within the collector gallery 409 not shown in Fig. 7 to enhance clarity. It also creates a zone of localized increase in strain along the flat plate (not shown separately) that redirects water into the turbine intake 403. By withdrawing a relatively small volume of water into the slot 501, a local minimum in strain is created that guides fish into the collector gallery 409. That is, the pattern in strain created by the OH-SBC 401 in conjunction with the existing pattern in strain created by flow into the turbine 403 intake creates a local minimum 413 in strain that guides fish ~~413~~ into the slot 501 of the collector gallery 409. By enclosing the eddy 101 caused by the dam structure 402 and the turbine intakes 403 to within the collector gallery 409, a preferred embodiment of the present invention eliminates competing hydraulic cues from the vicinity of the slot 501 to the collector gallery 409. Initially, the extension 40~~8~~7 also compresses the vertical velocity profile (i.e., locally increases the absolute value of $\frac{\partial u}{\partial z}$) as the flow 405 dives towards the turbine intake 403. However, after the streamlines 405 are first trained downward, the slot 501 in the OH-SBC 401 allows the

streamlines 405 to expand, i.e., the absolute value of $\frac{\partial u}{\partial z}$ decreases most gradually towards the slot 501 to the gallery 409. This simulates the "natural" hydraulic cue that fish use to locate the center of a channel 8. This hydraulic cue is further reinforced by the gradual withdrawal of water out of the collector gallery 409 to convey the fish around the dam 402. The NC-SBC 400 may be adjusted to meet changes in powerhouse operation and dam forebay water levels. An articulating extension 410 partially controls the angle of attack of the water that flows under the collector gallery 409. Adjustable attachment points 412 at the face of the dam 402 allow the OH-SBC 401 to be raised and lowered to optimize its efficiency as water levels fluctuate. In one embodiment, a hydrodynamic sensor 411 monitors water velocity and other hydraulic conditions to permit remote adjustment of the articulating extension 410 as well as to determine when the height of the OH-SBC 401 is optimized. In certain environments, such as spring runoff, trash accumulates over the top of the OH-SBC 401. If trash control is required, then a trashboom (not separately shown) can be installed upstream of the leading edge 414 of the wedge extension 407.

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Replace the paragraph beginning at page 15, line 25 with:

The relatively deep location of the bottom slot 501 of the collector gallery 409 minimizes the effect of daytime surface light on the efficiency of the OH-SBC 401 to attract fish into the bottom slot 501. Therefore, unlike conventional designs with surface oriented openings, a preferred embodiment of the present invention functions with nearly equal efficiency in all lighting conditions. The collector gallery 409 is relatively dark and characterized by a relatively low-energy hydraulic regime. Therefore, secondary stimuli, such as artificially-produced light or sound, may increase the efficiency of the NC-SBC 400.

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Replace the paragraph under "ABSTRACT" with:

A system and method for guiding fish that migrate is provided. A preferred embodiment is affixed to a dam having intakes that: a) generate hydroelectric power and b) serve as a natural hydraulic cue for fish that, once attracted to the intake, ~~are converted to pet food~~ may be injured or killed traversing the intake. A device resembling an oversize kitchen exhaust fan hood, with

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extension, is affixed adjacent the upstream side of a stream barrier that otherwise precludes fish from safely passing. The device simulates a naturally occurring hydraulic cue that fish use to migrate and may be used to defeat competing detrimental hydraulic cues. Also provided are embodiments to enable adjustment of the device to meet changing hydraulic conditions; to preclude the accidental provision of competing negative cues or stimuli; and to complement the simulated natural hydraulic cue provided by the device through using stimuli such as light, sound or combinations thereof.